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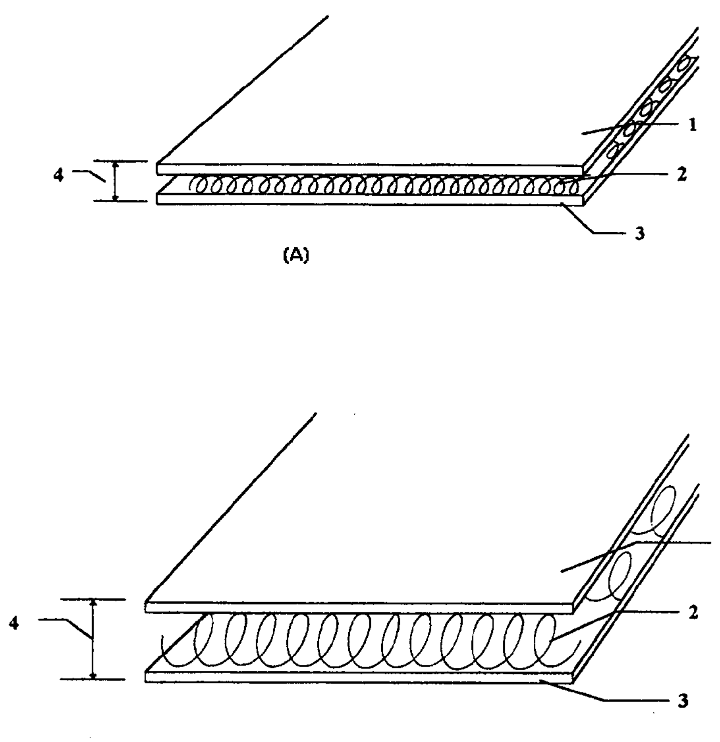
(54) Title: ADAPTIVE THERMAL INSULATION MATERIAL

(57) Abstract

This invention is a construction which provides one level of thermal insulation while under one set of conditions and can automatically change to provide a different level of thermal insulation under a different set of conditions. An important element of this invention is that the construction contains a spacer material (2) that is dynamically responsive to changes in temperature. The incorporation of this material (2) in a fabric construction yields dynamic, adaptive, thermal insulation. This adaptive, insulative, fabric construction can then be made into any number of useful articles including, but not limited to, apparel items for firefighters, emergency response personnel, foundry workers, etc. When used in conjunction with waterproof, breathable fabric laminates, this invention can be used in thermally adaptive, thermally insulative, lightweight, breathable apparel items.



(B)

TITLE OF THE INVENTION

ADAPTIVE THERMAL INSULATION MATERIAL

CROSS-REFERENCE TO RELATED APPLICATIONS:

This application is a continuation-in-part of application Serial No. 08/904,365 filed August 1, 1997.

BACKGROUND OF THE INVENTION

Conventional firefighter turnout garments typically are comprised of three layers. An outer shell typically made from a polybenzimidazole (PBI)/Kevlar® blend or Nomex® in the form of woven cloths. The outer shell primarily provides protection from mechanical threats. A second layer is a moisture barrier which provides protection from liquid water and other fluids. The state-of-the-art moisture barriers provide this liquid penetration resistance while remaining permeable to water vapor. They are called "breathable" because of their water vapor permeability. These "breathable" moisture barriers provide greater comfort to the wearer. One very common, breathable, moisture barrier is CROSSTECH™ laminate available from W. L. Gore and Associates, Inc. The performance of this moisture barrier is achieved by its unique construction. It is a composite of a microporous expanded polytetrafluoroethylene membrane layer and a monolithic, breathable polymer layer laminated to a third fabric layer. This third layer is typically a thick, lofty, quilted, non-woven/woven fabric designed to provide thermal insulation. This thermal insulation provides good thermal insulation but is heavy, encumbering, and typically not very breathable. Alternatively, thin thermal insulation layers may be lightweight, less encumbering, and breathable but do not provide adequate thermal insulation.

SUMMARY OF THE INVENTION

This invention is directed to a thermally adaptive thermal insulation material that provides the best of both these scenarios. This invention provides a highly breathable, lightweight material which provides one level of thermal insulation while under one set of conditions and which can automatically change to provide a different level of thermal insulation under a different set of conditions. This material layer can be made to respond to any number of

stimuli, but of primary importance to this invention is that this material layer is dynamically responsive to changes in temperature. The incorporation of this material layer in to a fabric construction yields a dynamic, adaptive, thermal insulation. This adaptive, insulative, fabric construction can then be made into any number of useful articles including but not limited to apparel items for firefighters, emergency response personnel, foundry workers, etc. When used in conjunction with waterproof, breathable fabric laminates, this invention can be used in thermally adaptive, thermally insulative, lightweight, breathable apparel items.

Specifically, the invention can be defined as a thermally responsive material which changes shape in response to a change in the thermal energy level of the surrounding environment, said responsive material positioned between two adjacent surfaces in a manner such that the two surfaces are spacially moved relative to one another as a result of said change in shape.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary, as well as the following detailed description of a preferred embodiment of the invention, will be better understood when read in conjunction with the appended drawings.

Figure 1 is a schematic of a thermally adaptive insulation material formed from a helical trained shape memory wire located between two adjacent fabric layers. Figure 1A depicts a typical thermally adaptive insulation lay-up in its cool, thin conformation. Figure 1B depicts the same lay-up in its thicker, higher temperature conformation.

Figure 2 is a schematic of a thermally adaptive insulation material formed from a trough-shape trained shape memory wire located between two adjacent fabric layers. Figure 2A depicts a typical thermally adaptive insulation lay-up in its cool, thin conformation. Figure 2B depicts the same lay-up in its thicker, higher temperature conformation.

Figure 3 is a schematic of a thermally adaptive insulation material formed from a coil shape trained shape memory wire located between two adjacent fabric layers. Figure 3A depicts a typical thermally adaptive insulation lay-up in its cool, thin conformation. Figure 3B depicts the same lay-up in its thicker, higher temperature conformation.

Figure 4 is a schematic of a thermally adaptive insulation material formed from bi-metallic strips located between two adjacent fabric layers. Figure 4A depicts a typical thermally adaptive insulation lay-up in its cool, thin

conformation. Figure 4B depicts the same lay-up in its thicker, higher temperature conformation.

Figure 5 is a schematic of a thermally adaptive insulation material formed from bi-metallic snap disks located between two adjacent fabric layers. Figure 5A depicts a typical thermally adaptive insulation lay-up in its cool, thin conformation. Figure 5B depicts the same lay-up in its thicker, higher temperature conformation.

DETAILED DESCRIPTION OF THE INVENTION

This invention provides a thermally adaptive spacer layer. The major component is a material which changes shape when exposed to changes in temperature. The classes of such materials include shape memory alloys, bi-metallic combinations, and other thermally responsive materials. The change in shape of these materials results in a change in the three dimensional space that the material occupies. Thus, when located between any two surfaces, these materials can be used to change the air gap between the surfaces with changes in temperature; thereby changing the thermal insulation properties of the construction. The extent of change in the space between these surfaces can be adjusted by the configuration and selection of the thermally adaptive materials. For example, the shape memory material can be a coiled wire which lies flat at one temperature, but which at another temperature, the coils assume an erect, three dimensional configuration. This configuration, of course, increases the z space gap when the material is between two adjacent surfaces

Other shape memory materials, especially bi-metallic co-linear strips might assume a bent configuration, which when inserted between two surfaces cause the surfaces to be forced away from one another. Shape memory plastics are also available which can accomplish the desired result. Mitsubishi Shape Memory Polymer, which is believed to be a specialized polyurethane, is one such material. The selection of the thermally adaptive spacer material is dependent on the desired final spacer performance requirements.

All these shape memory devices change shape in response to a stimuli. Those that change shape in response to temperature changes are preferred where the changes in temperature are sufficient to stimulate the desired change in the thermally adaptive spacer thickness.

Either or both surfaces between which this thermally adaptive spacer material is located may be either flexible or rigid. Many useful applications of

this invention pertain to the use of this thermally adaptive spacer between flexible substrates. When located between flexible fabric substrates, a composite construction can be produced which is lightweight, flexible, and able to provide adaptive thermal insulation.

Typically, the thermally adaptive spacer layer is attached to at least one of the two adjacent surface layers. Preferably it is attached to both. Either way, one or both surfaces move toward or away from each other as the thermally adaptive spacer material changes shape and thereby the space between the layers.

The thermally adaptive spacer layer may, in some instances, also be free-standing between the two adjacent surfaces. In yet another configuration, the thermally adaptive spacer material can be attached to at least one of the adjacent layers. Additional layers may also be included in the total construction.

Potential applications for this dynamically adaptive thermal insulation invention include but are not limited to the following apparel items such as garments, gloves, and helmets which might be used by firefighters, foundry workers, chemical and petroleum plant workers, emergency medical personnel, race car drivers, astronauts, and any other personnel where a threat of high temperature exposure exists.

The specific adjacent layers in the construction are chosen from a wide range of materials. The thermal insulation provided by this invention results from the thickness change in the total construction brought about by the transformation of the thermally adaptive spacer material. Thus, this invention may be used to provide adaptive thermal insulation between any two surfaces, at least one of which is flexible and moveable. The thermally adaptive spacer layer need only have one flexible surface on which to function. Preferably both are flexible and moveable. The adaptation of this thermally adaptive spacer layer can be either gradual, occurring over a wide temperature range, or abrupt, occurring over a narrow temperature range.

In one aspect, the invention may be utilized to provide adaptable thermal insulation between fabric layers. In one configuration, this invention is employed between a shell fabric and a liner fabric whereby the gap between these fabric layers is forced to change by the activation of the thermally adaptive spacer material. This thermally adaptive spacer material may or may not be part of or directly attached to either of the adjacent fabric layers.

This invention may be used in conjunction with a waterproof fabric or waterproof laminate layer to produce a construction suitable for apparel applications such as but not limited to firefighting. By apparel is meant any covering from head to toe, e.g. hats, bands, footwear, garments, gloves and the like. In this configuration, the outer fabric may be constructed of a high temperature material such as but not limited to Nomex® or PBI/Kevlar®. The inner waterproof layer may be a breathable laminate such as but not limited to CROSSTECH® moisture barrier used in the Examples herein. Additional fabric layers may also be included in the total garment lay-up. Any arrangement of these fabric and thermally adaptive spacer layers will perform the thermally adaptive function of this invention provided the thermally adaptive spacer is between two of the layers. By fabric is meant a material comprised of fibers, and including wovens, nonwovens, knits, felts, fleece, and the like. The fabric will contain interstices or pores, i.e. passage ways, through the fabric. Fabrics can be made of synthetic polymers such as, but not limited to, polyamides, polyesters, polyacrylates, polyolefins, and the like. Waterproof or water resistant, but breathable materials useful herein include the usual known microporous materials, such as expanded PTFE, polyolefines, polyurethane, as well as nonporous polyurethanes, copolyesters, copolyesterethers and the like.

EXPERIMENTAL MEASUREMENTS

Thickness

The thickness measurements used in the evaluation of the performance of this invention are summarized herein. Because this invention changes thickness at elevated temperatures, a test method was developed which allowed thickness to be measured at both room temperature and at elevated temperatures.

A standard pedestal mounted micrometer was used to measure the thickness at various temperatures. A one inch diameter foot was attached to the micrometer such that micrometer probe rested evenly on the test specimen. The type of micrometer chosen utilized a 0.5 pound weight to create the desired force under which the thickness was to be measured. The thickness of the sample was first measured at room temperature. The micrometer load was then removed, and heat was applied to the sample. A heat gun was used to apply the heat in this instance, although any suitable heat source could be used to create the desired temperature rise. Once the temperature reached the desired temperature above the transition temperature

described in this invention, the load was reapplied to the micrometer and a second thickness measurement taken. These difference between these thickness measurements are cited in the examples below and uniquely show that this invention undergoes dramatic changes in thickness as a function of temperature.

TPP

Thermal protection is measured by the thermal protective performance (TPP) test method described in the 1971 NFPA, 1997 Edition.

6 inch X 6 inch squares of fabric construction are mounted in a frame and placed on a table with a calorimeter on top. An opening in the table allows heat to be applied to the bottom side of the fabric. Radiant heat is applied at a rate of 2 calories/cm^2 second and the amount of time which would be required to produce a second degree burn is measured. Thus, the higher the TPP value, the better the heat resistant performance of the fabric. The constructions of the Examples provide TPP values of 30 seconds or more.

Examples 1 through 5 depict various embodiments of this invention. It should be understood, however, that the invention is not limited to the precise arrangements, constructions, nor orientations shown in these examples.

EXAMPLE 1:

The preferred embodiment of this invention utilizes a dynamic thermal insulation spacer made from a shape memory material. One such shape memory material is a shape memory wire sold by Shape Memory Applications, Inc., Santa Clara, California. The wire diameter used in this example was 0.011 inches although other wire diameters will work and have been successfully utilized. In this embodiment, the shape memory wire was trained in the form of a helical coil and placed between the flexible fabric layers which comprise the adjacent layers which are to be separated by the thermally adaptive spacer material. The complete fabric lay-up of this embodiment is shown in Figure 1 where layer 1 is a 7.5 oz/yd^2 PBI/Kevlar woven fabric from Hoechst Celanese and layer 3 is CROSSTECH® moisture barrier from W. L. Gore and Associates, Inc. Item 2 is the helical trained shape memory wire.

At temperatures below the transition temperature of the shape memory material, the shape memory wire is relaxed and lies relatively flat between the adjacent layers (as shown in Figure 1A). The total thickness (4) of the construction shown in Figure 1A is approximately 4 mm at 21°C. At

temperatures near, equal to, or above the 65°C to 75°C transition temperature of the shape memory material used in this example, the wire assumes the helical shape to which it was previously trained. This transformation from a relaxed flat conformation to a three dimensional helix actively separates the adjacent layers as depicted in Figure 1B. The total lay-up thickness (4) of the construction shown in Figure 1B is approximately 17mm at 100°C. Upon cooling to temperatures below the transition temperature of the shape memory material, the wire becomes more ductile thereby allowing the thick thermal insulation to return to its thin, flattened conformation as shown in Figure 1A. Subsequent reheating to a temperature above the shape memory wire transition temperature again returns the shape memory wire to its three dimensional helical shape. This cycle can be repeated through many cycles.

The shape memory wire in this embodiment was trained by first wrapping it around a cylinder of the chosen final helix diameter. A threaded rod was used in this example although many other cylindrical shapes will working including but not limited to metal tubing, pipe, or solid metal rods. The cylinder diameter determines the approximately gap size which will subsequently be created by this thermally activated spacer material. The rod containing with the wrapped wire was then heat treated at approximately 500°C for approximately 10 minutes. The wire wrapped rod was then allowed to cool, and the wire unwrapped.

The cool shape memory wire could optionally then be attached to one of the adjacent layers 1 or 3. Any number of attachment means can be used. This embodiment utilized a thermosetting adhesive to attach the helical coils of shape memory wire to the fabric in parallel rows.

The TPP of the construction was 33.

EXAMPLE 2:

This embodiment utilizes a dynamic thermal insulation spacer also made from shape memory wire, such as that sold by Shape Memory Applications, Inc., Santa Clara, California. The wire diameter used in this example was 0.008 inches although other wire diameters will work and have been successfully utilized. The shape memory wire was trained in the form of a trough-shape and placed between two flexible fabric layers which comprise the adjacent layers which are to be separated by this thermally adaptive spacer material. The complete fabric lay-up of this embodiment is shown in Figure 2 where layer 5 is a 7.5 oz/yd^2 PBI/Kevlar woven fabric from Hoechst Celanese

and layer 7 is CROSSTECH® moisture barrier from W. L. Gore and Associates, Inc. Item 6 is the trough-shaped shape memory wire which can optionally be sewn to either or both of the adjacent fabric layers.

At temperatures below the 65°C to 75°C transition temperature of the shape memory material, the shape memory wire is relaxed and lies relatively flat between the adjacent layers as shown in Figure 2A. The total thickness (8) of the construction shown in Figure 2A is approximately 2 mm at 21°C. At temperatures near, equal to, or above the transition temperature of the shape memory material, the wire assumes the trough shape to which it was previously trained. This transformation from a relaxed, thin, flat conformation to the three dimensional trough-shape actively separates the adjacent layers as shown in Figure 2B. Note, the orientation of Figure 2B has been rotated 90° compared to Figure 2A in order to more effectively show the lifted sides of the trough-shaped memory wire (6). The total lay-up thickness (8) of the construction shown in Figure 2B is approximately 19 mm at 100°C. Upon cooling to temperatures below the transition temperature of the shape memory material, the wire again relaxes, and the thick thermal insulation can return to its thin flattened conformation shown in Figure 2A. This adaptive thermal insulation material can repeatedly undergo these reversible transformations from thin to thick and back to thin again.

The shape memory wire in this embodiment was trained in the form of a trough-shape using a metal bar which contained pegs protruding out from each side in an alternating fashion along the length of the bar and located approximately 0.25 inches in from the edge of the bar. The shape memory wire was then attached to this jig by starting at one end of the bar and proceeding to the other by wrapping the wire around alternating pegs a back-and-forth manner down the length of the bar until the other end is reached. The distance of the pegs from the edge of the bar over which the wire is wrapped determines the approximately gap size which will subsequently be created by this thermally activated spacer material. This bar containing with the wrapped wire was then heat treated at approximately 500°C for approximately 10 minutes. The wire wrapped bar was then allowed to cool, and the wire unwrapped.

The cool shape memory wire can then optionally be attached to one of the adjacent layers 5 or 7. The support layer may be one or more of the layers which will ultimately be part of or adjacent to this spacer material in the final construction. Any number of attachment means can be used. In this

embodiment, the trained wire was attached to a support layer by sewing down the center of the trough such that the sides were free to lift freely upon heating.

EXAMPLE 3:

This embodiment utilizes a dynamic thermal insulation spacer also made from shape memory wire, such as that sold by Shape Memory Applications, Inc., Santa Clara, California. The wire diameter used in this example was 0.020 inches although other wire diameters will work and have been successfully utilized. The shape memory wire was trained in a conical-shape and placed between the two flexible fabric layers thereby making the adaptive thermal insulation material of this invention. The complete fabric lay-up of this embodiment is shown in Figure 3 where layer 9 is a 7.5 oz/yd^2 PBI/Kevlar woven fabric from Hoechst Celanese and layer 11 is CROSSTECH® moisture barrier from W. L. Gore and Associates, Inc. Item 12 is the coiled shape memory wire.

In this embodiment, several of the coils of shape memory spirals were placed between two layers of fabric. As shown in Figure 3A, the total lay-up thickness (12) of this construction was less than approximately 3 mm at 21°C. When the fabric layers were exposed to temperatures near, equal to, or above the transition temperature of the shape memory material, the wire assumed the conical shape to which it was previously trained. This transformation from a relaxed flat conformation to the three dimensional conical shape actively separates the adjacent layers as shown in Figure 3B. The total lay-up thickness (12) of the construction shown in Figure 3B is approximately 10 mm at 100°C. Upon cooling to temperatures below the transition temperature of the shape memory material, the wire again relaxes, and this thick thermal insulation material returns to its thin, approximately 3 mm, flattened conformation shown in Figure 3A. This thermally adaptive spacer material reversibly undergoes these transformations from thin to thick and back to thin again.

The shape memory wire was trained in a conical-shape using a machined metal cone. The shape memory wire was then wrapped around this cone. The dimensions of the cone determine the approximate gap size which will subsequently be created by this thermally activated spacer material.

This wire wrapped cone was then heat treated at approximately 500°C for approximately 10 minutes. The wire wrapped cone was then allowed to cool, and the wire unwrapped. At temperatures below the 65°C to 75°C transition temperature of the shape memory material, these cone-shaped

trained wires actually lie flat and appear as a wire spiral. These wire spirals were then placed between the layers between which the adaptive thermal insulation is desired (Figure 3A). Many other discrete, shape memory parts can be used in place of the conically trained shape memory wire such as but not limited to shape memory snap disks and clover-leafs provided that parts can be transformed from a low profile (i.e., flat) conformation to a higher profile, 3-dimensional conformation with changes in temperature.

EXAMPLE 4:

This embodiment utilizes a dynamic thermal insulation spacer made from bi-metallic strip such as that sold by Crest Manufacturing Company in Rhode Island. The complete fabric lay-up of this embodiment is shown in Figure 4 where layer 13 is a 7.5 oz/yd^2 PBI/Kevlar woven fabric from Hoechst Celanese and layer 15 is CROSSTECH® moisture barrier from W. L. Gore and Associates, Inc. Item 14 is the bi-metallic strips. The bi-metallic strips used in this example were ASTM Type TM2 alloy and were approximately 0.010 inches thick, 0.25 inches wide, and 2 inches long, although other dimension strips will work and have been successfully utilized. The specific bi-metallic strip was chosen to provide maximum curvature over the temperature range of interest.

At temperatures below the approximately 50°C, transition temperature(s) of the bi-metallic strip material, these strips lie flat. These bi-metallic strips were then placed between the layers between which the adaptive thermal insulation is desired (Figure 4A). The total lay-up thickness (16) of the construction shown in Figure 4A was less than approximately 3 mm at 21°C.

In this example, several of these bi-metallic strip were placed between two layers of fabric such that when the fabric layers were exposed to temperatures near, equal to, or above the transition temperature of the bi-metallic strip material, the strip changed from flat to curved. This transformation from a relaxed flat conformation to the three dimensional curved shape actively separates the adjacent layers as shown in Figure 4B. The total thickness (16) of the construction shown in Figure 4B was approximately 9mm at 150°C. Upon cooling to temperatures below the transition temperature of the bi-metallic strip material, the bi-metallic strip again relaxes, and the thick thermal insulation returns to its thin, flat conformation as shown in Figure 4A. This adaptive thermal insulation material reversibly undergoes these transformations from thin to thick and back to thin again.

EXAMPLE 5:

This embodiment utilizes a dynamic thermal insulation spacer made from bi-metallic snap disks such as those sold by Crest Manufacturing Company in Rhode Island. The complete fabric lay-up of this embodiment is shown in Figure 5 where layer 17 is a 7.5 oz/yd^2 PBI/Kevlar woven fabric from Hoechst Celanese and layer 19 is CROSSTECH® moisture barrier from W. L. Gore and Associates, Inc. Items 18 are the bi-metallic snap disks. The bi-metallic snap disks used in this example were ASTM Type TM2 alloy and were approximately 0.012 inches thick, and 1.0 inches in diameter, although other sizes will work. The specific bi-metallic snap disk was chosen to provide maximum curvature over the temperature range of interest.

At temperatures below the approximately 50°C, transition temperature(s) of the bi-metallic material, these disks lie flat. These bi-metallic strips were then placed between the two layers which are to be thermally adaptively separated (Figure 5A). The total lay-up thickness (20) of the construction shown in Figure 5A was less than approximately 3 mm at 21°C.

In this example, several of these bi-metallic snap disks were placed between two layers of fabric such that when the fabric layers were exposed to temperatures near, equal to, or above the transition temperature of the bi-metallic material, the disks would snap into their curved shape. This transformation from a relaxed flat conformation to the three dimensional curved shape actively separates the adjacent layers as shown in Figure 5B. The total thickness (20) of the construction shown in Figure 5B was approximately 4mm at 150°C. Upon cooling to temperatures below the transition temperature of the bi-metallic strip material, the bi-metallic strip again relaxes, and the thick thermal insulation returns to its thin, flat conformation as shown in Figure 5A. This adaptive thermal insulation material reversibly undergoes these transformations from thin to thick and back to thin again.

CLAIMS:

1. A fabric construction comprising at least two layers of fabric, and including a thermally responsive material which has one spatial configuration above one temperature and another below said temperature, said thermally responsive material positioned between said two layers of fabric in a manner in which at least one of said layers is spatially moved relative to the other as a result of said change in spatial configuration.

2. The fabric construction of claim 1 wherein the thermally responsive material lies flat between the two layers of fabric at one temperature and takes a three dimensional configuration at a higher temperature.

3. The fabric construction of claim 1 wherein at least one of said layers of fabric includes a liquid water resistant but water vapor permeable material.

4. The fabric construction of claim 3 wherein the thermally responsive material lies flat between the two layers of fabric at one temperature and takes a three dimensional configuration at a higher temperature.

5. The fabric construction of claim 1 wherein one of said two layers of fabric is affixed to the thermally responsive material.

6. The fabric construction of claim 1 wherein the thermally responsive material is partially embedded in at least one of said two layers.

7. The fabric construction of claim 1 wherein the thermally responsive material is a shape memory material.

8. The fabric construction of claim 7 wherein the shape memory material is a wire coil.

9. The fabric construction of claim 1 wherein the thermally responsive material comprises a plurality of wire coils arranged in substantially parallel rows.

10. The fabric construction of claim 7 wherein the shape memory material is a polymer.

11. The fabric construction of claim 7 wherein the shape memory material is an alloy.

12. The fabric of construction of claim 7 wherein the shape memory material is a bimetallic wire.

13. The fabric construction of claim 3 wherein one of said two layers of fabric is affixed to the thermally responsive material.

14. The fabric construction of claim 3 wherein the thermally responsive material is partially embedded in at least one of said two layers.

15. The fabric construction of claim 3 wherein the thermally responsive material is a shape memory material.

16. The fabric construction of claim 15 wherein the shape memory material is a wire coil.

17. The fabric construction of claim 3 wherein the thermally responsive material comprises a plurality of wire coils arranged in substantially parallel rows.

18. The fabric construction of claim 15 wherein the shape memory material is a polymer.

19. The fabric construction of claim 15 wherein the shape memory material is an alloy.

20. The fabric of construction of claim 15 wherein the shape memory material is a bimetallic wire.

21. Apparel containing a fabric, which fabric has attached to it a thermally responsive material which reversibly changes its spatial configuration in response to a change in the thermal energy level of the surrounding environment.

22. The apparel of claim 21 wherein the thermally responsive material is located between two adjacent layers of the fabric.

23. The apparel of claim 22 wherein at least one of the two adjacent layers contains a liquid water resistant, but water vapor permeable material.

24. Apparel including the fabric construction as defined in claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 or 20..

25. Apparel adapted for fire-fighting applications, said apparel defined as in claim 24.

26. A fabric construction comprising at lest two layers of fabric, and including a thermally responsive material which has one spatial configuration above one temperature and another below said temperature, said thermally responsive material positioned between said two layers of fabric in a manner in which at least one of said layers is spatially moved relative to the other as a result of said change in spatial configuration;

said thermally responsive material lying flat between the two layers of fabric at one temperature and taking a three dimensional configuration at a higher temperature;

said fabric construction having TPP test value greater than 30 when the thermally responsive material is in its three dimensional configuration.

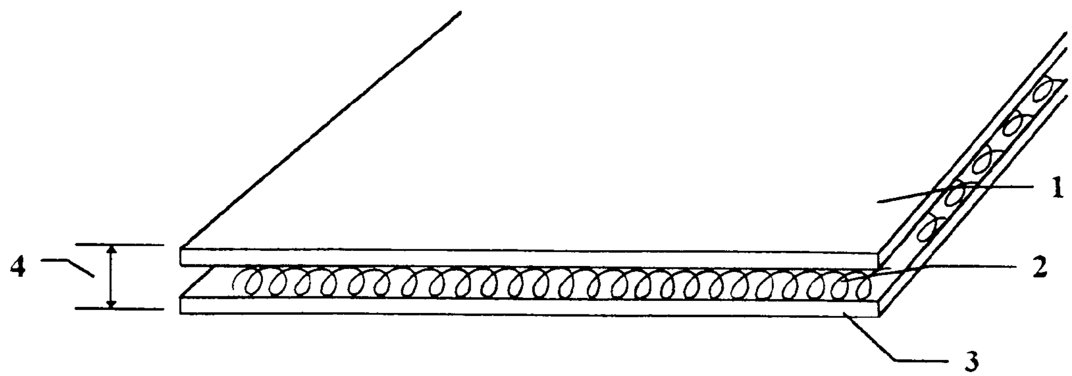


FIG. 1A

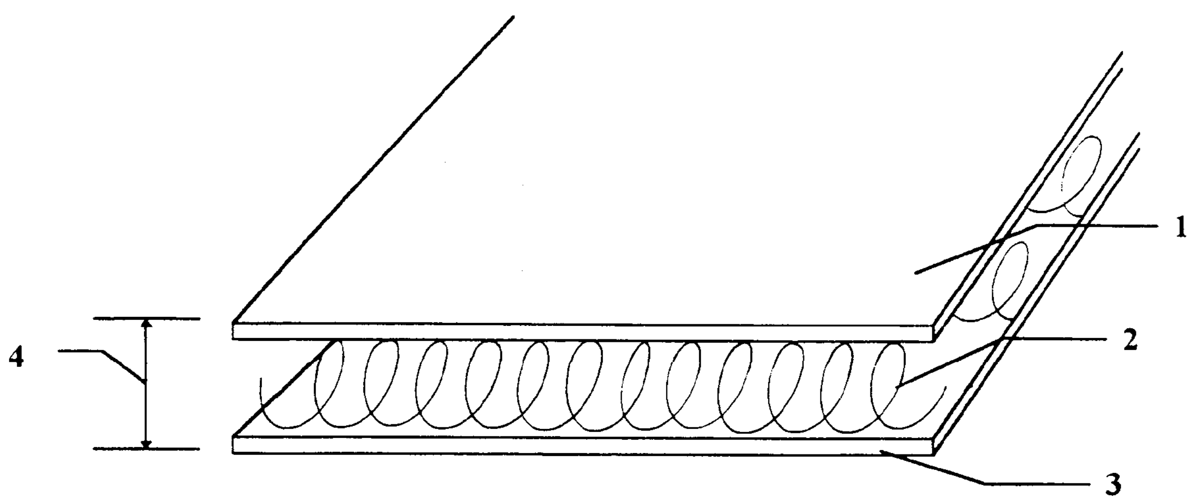


FIG. 1B

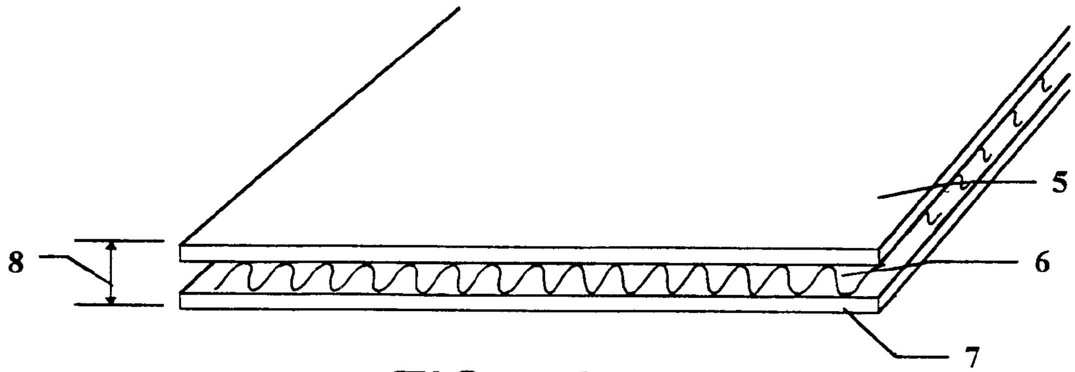


FIG. 2A

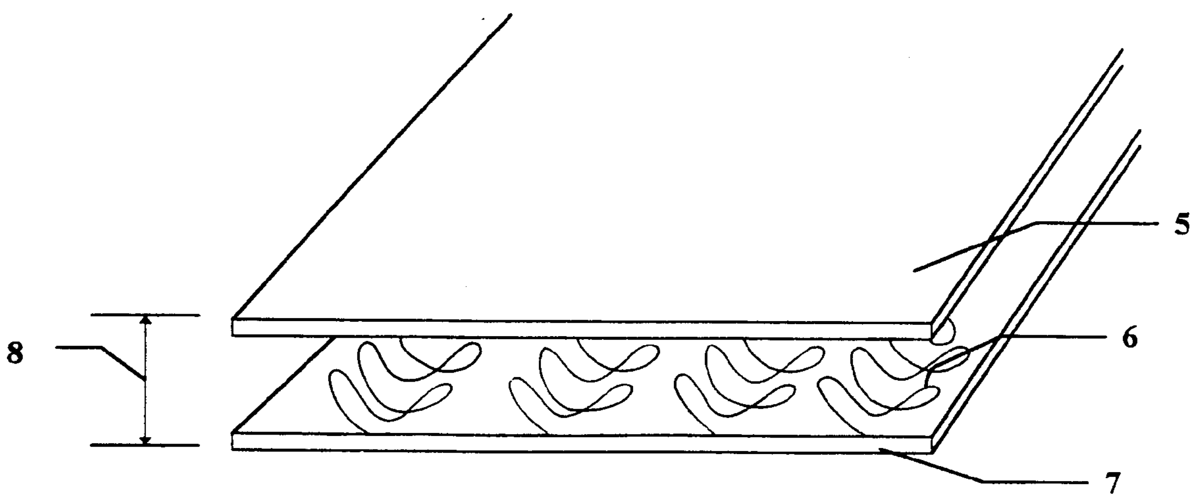


FIG. 2B

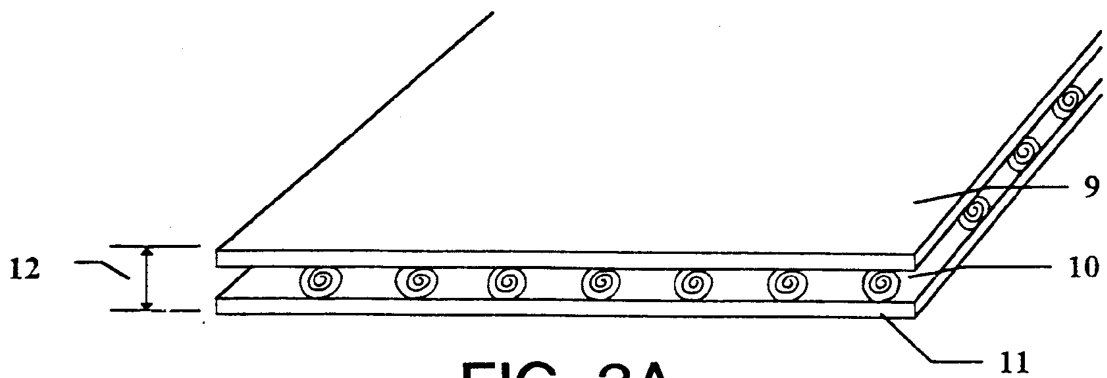


FIG. 3A

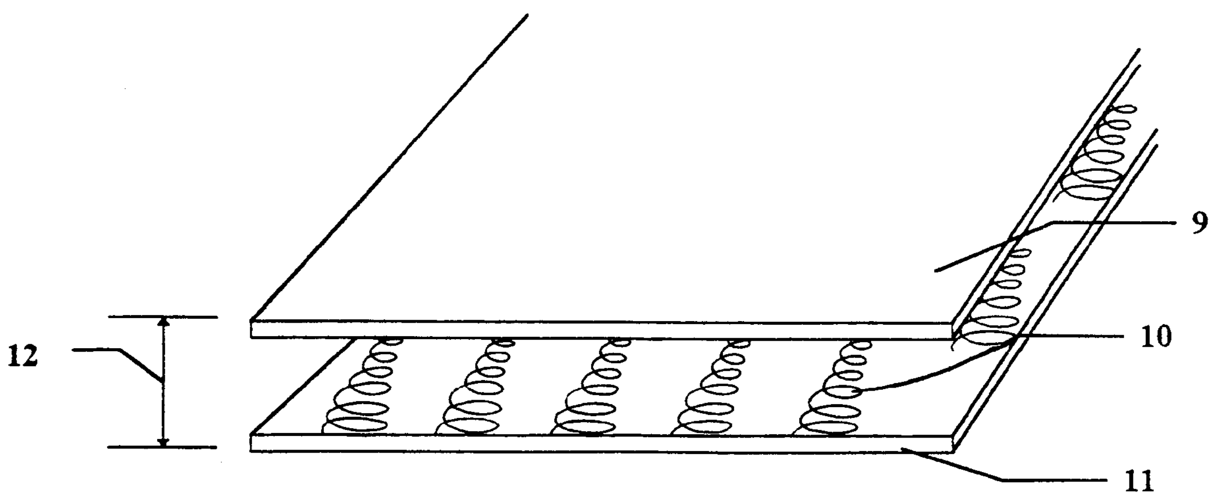


FIG. 3B

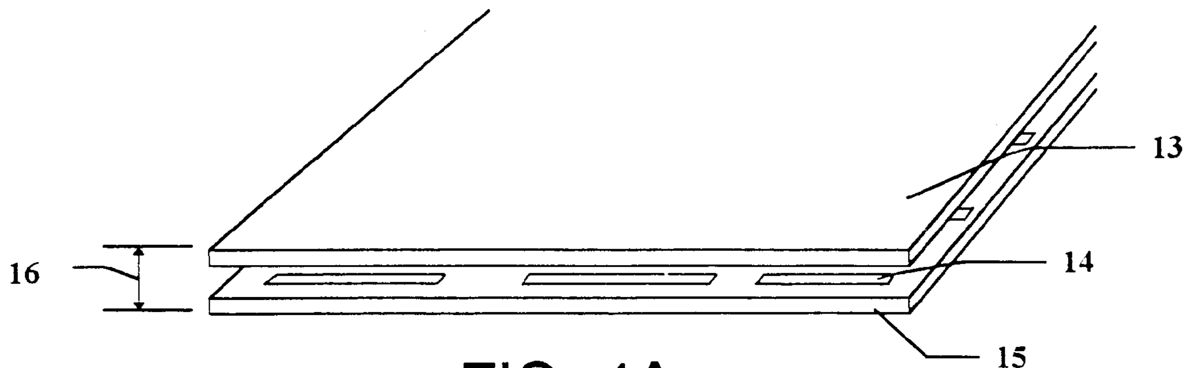


FIG. 4A

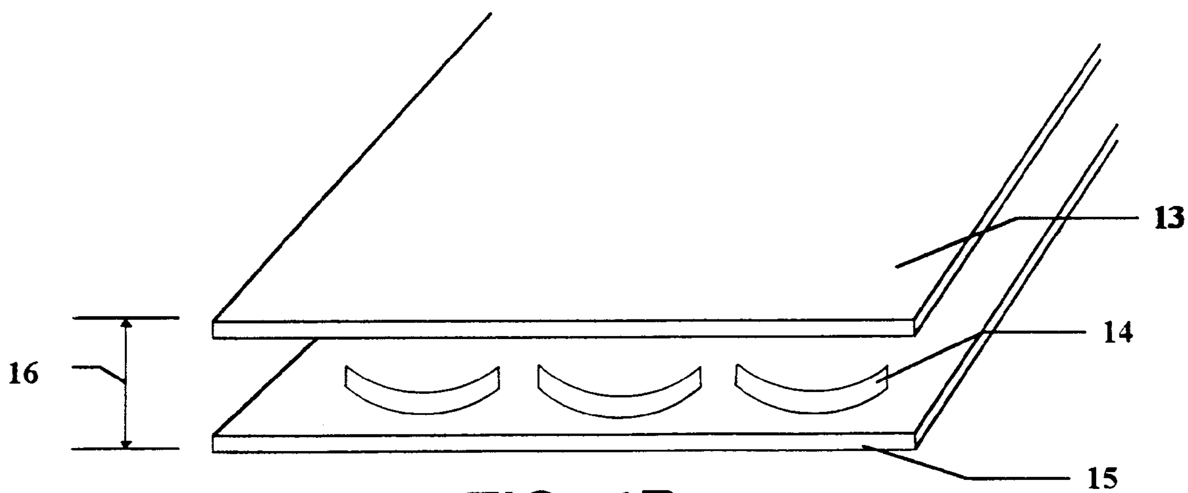


FIG. 4B

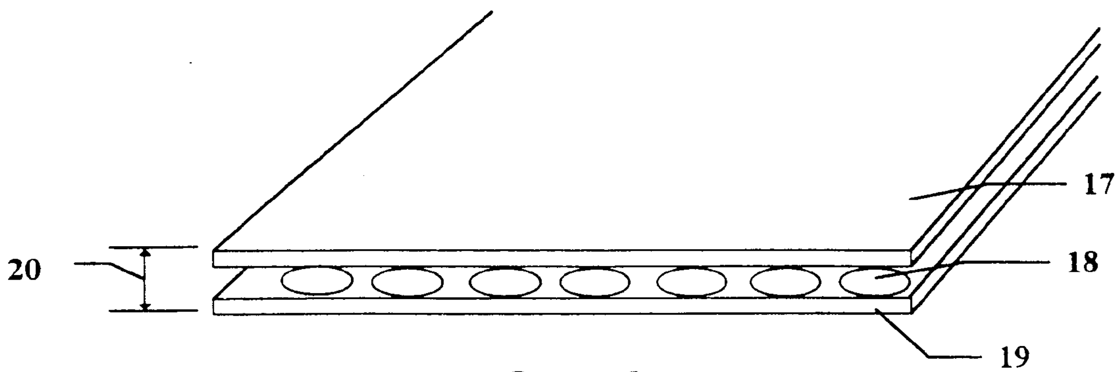


FIG. 5A

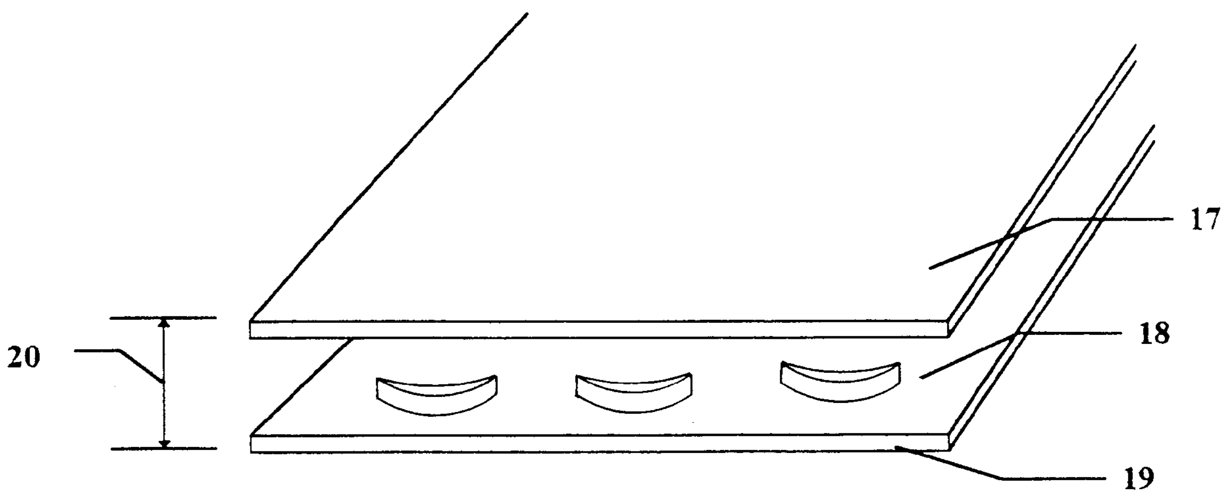


FIG. 5B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/15945

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A41D31/00 B32B7/04 B32B5/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A41D B32B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	GB 2 312 644 A (THE SECRETARY OF STATE FOR DEFENCE) 5 November 1997 see page 1, paragraph 3 - page 3, paragraph 4 see page 4, paragraph 5 - page 6, last paragraph; claims 1-14; figures 1-4 ---	1,2,4,6,7,9,15,18-20
A	GB 2 234 705 A (SECRETARY OF STATE FOR DEFENCE) 13 February 1991 see page 3, line 16 - page 4, line 21; claims 1-10; figures 1-6B ---	1,3,21-23
A	US 5 181 287 A (J. J. YANG) 26 January 1993 see the whole document --- -/--	1,21,22

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
25 November 1998	09/12/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Garnier, F

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INTERNATIONAL SEARCH REPORT

Int   tional Application No
PCT/US 98/15945

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 95 25038 A (FFV AEROTECH AB) 21 September 1995 see page 3, line 7 - page 7, line 22 ---	1,21
A	US 5 303 425 A (P. C. MELE) 19 April 1994 see column 2, line 25 - line 49; claims 1-4; figures 1-6 ---	1,21
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Int tional Application No
PCT/US 98/15945

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US 5181287	A	26-01-1993	NONE			
WO 9525038	A	21-09-1995	SE	503018	C	11-03-1996
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